AMENDMENTS TO THE DRAWINGS:

The attached nineteen (19) sheets of drawings include changes to Figures 1-17. These sheets, which include Figures 1-17 replaces the original thirteen (13) sheets including Figures 1-17. The drawings have all been amended to remove Japanese characters and to replace them with their English equivalents. Also, Figure 1 has been additionally amended to include character reference "PT," which had been previously omitted. Figures 2, 8, 13, 14 and 15 have been amended so that character references used to designate more than one different part in the drawings have been replaced as necessary in accordance with 37 C.F.R. § 1.84(p).

The present amendment adds no new matter to the drawings.

Attachment: Nineteen Replacement Sheets

Thirteen Annotated Sheets showing changes.

Annotated

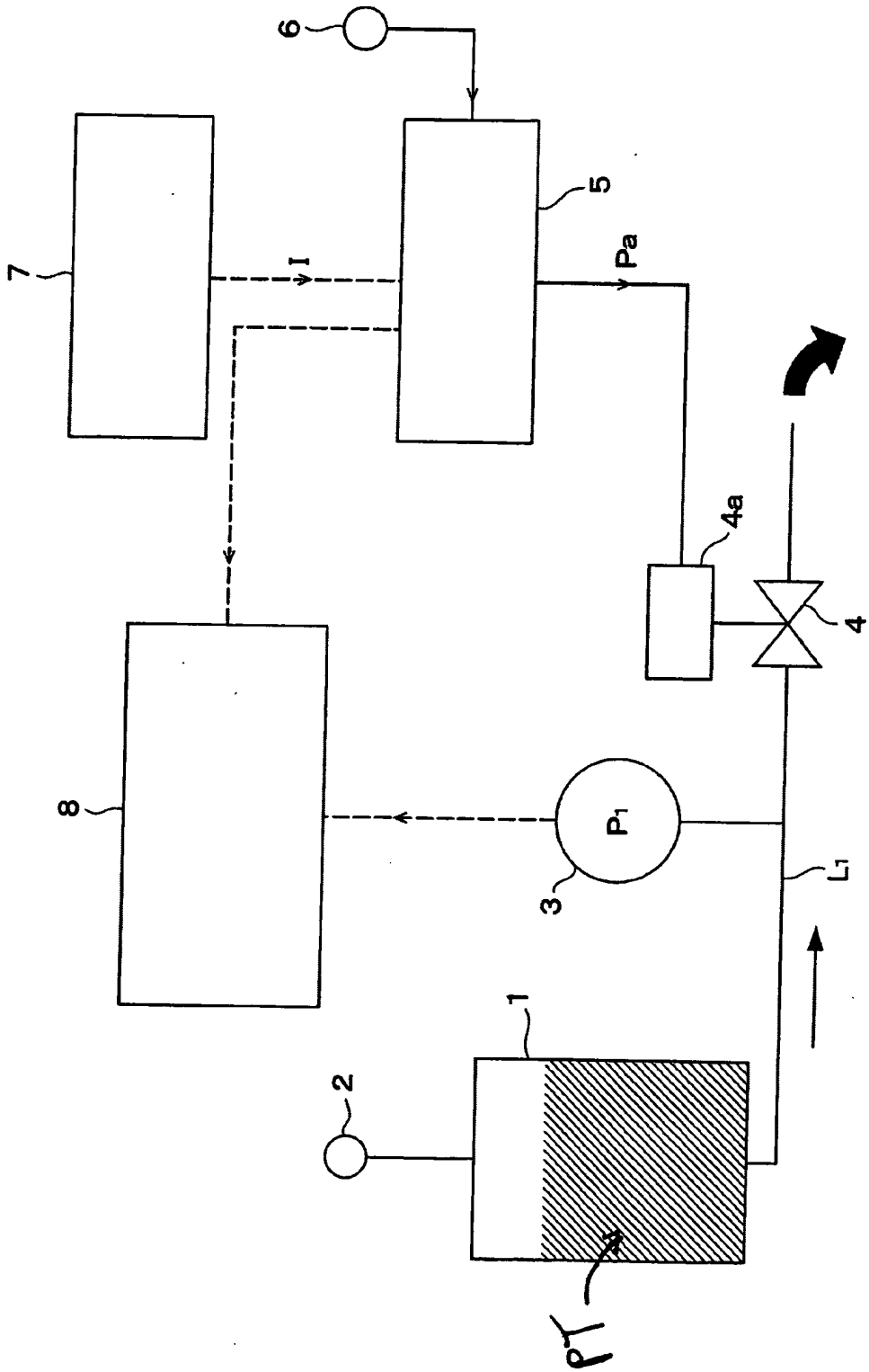


FIG. 1

Annotated

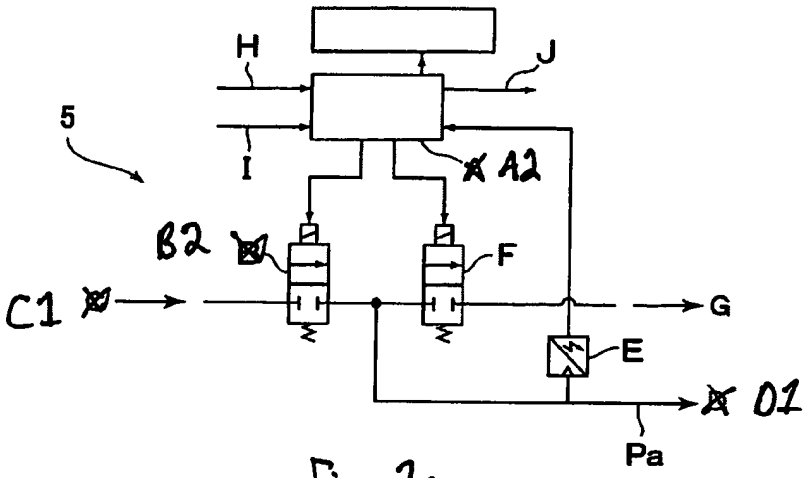


Fig. 2a

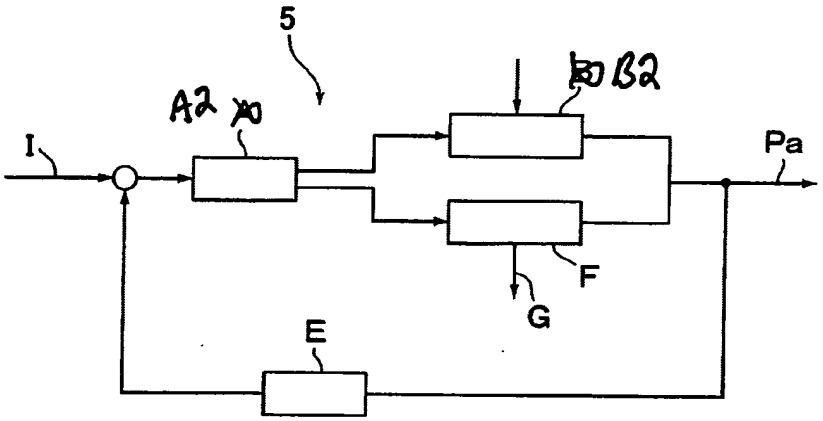


Fig. 2b

Annotated

[~~図3~~]

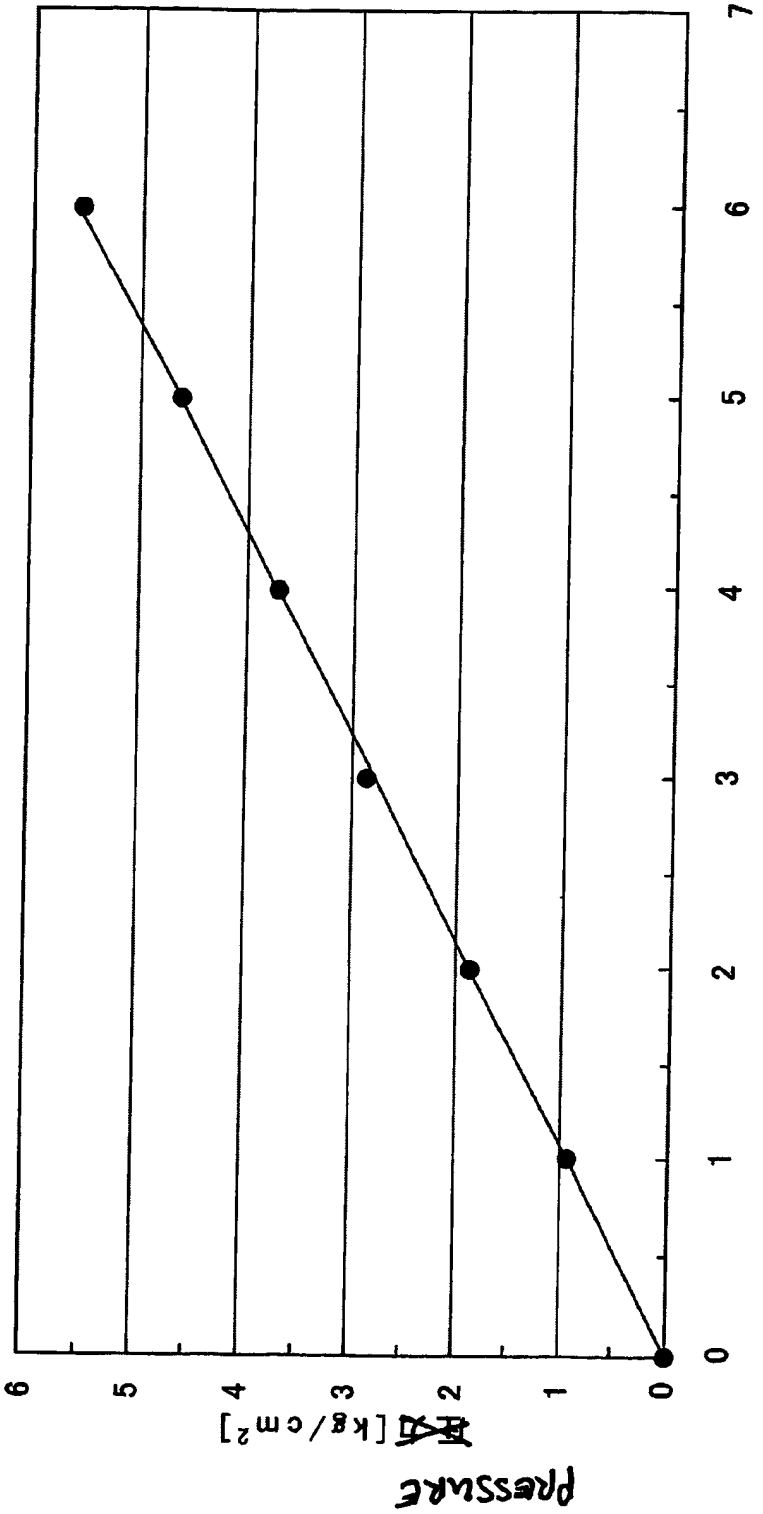


Fig. 3

Annotated

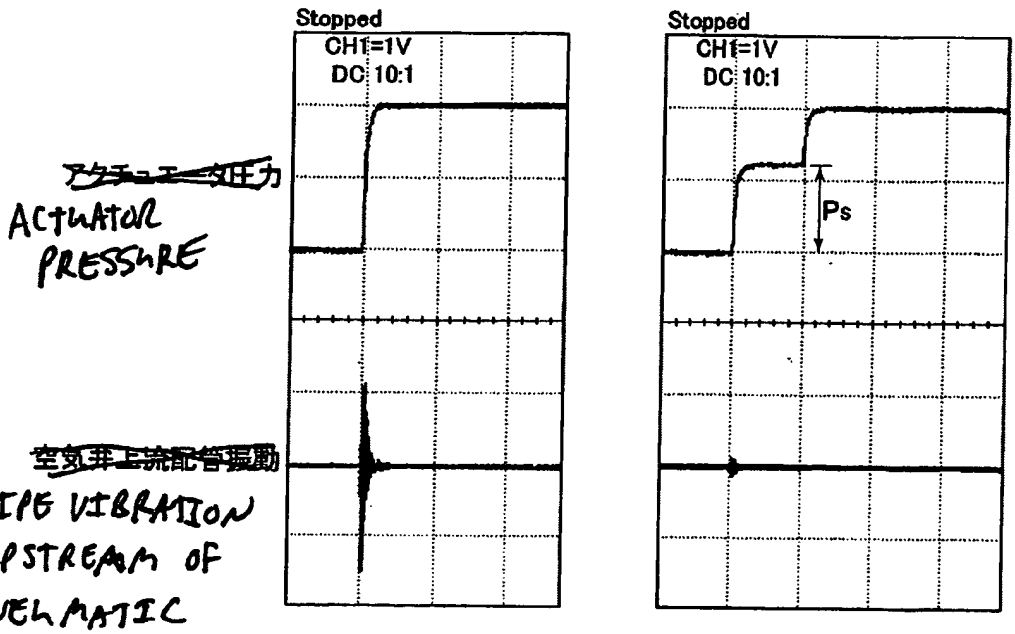


Fig. 4a

Fig. 4b

Annotated

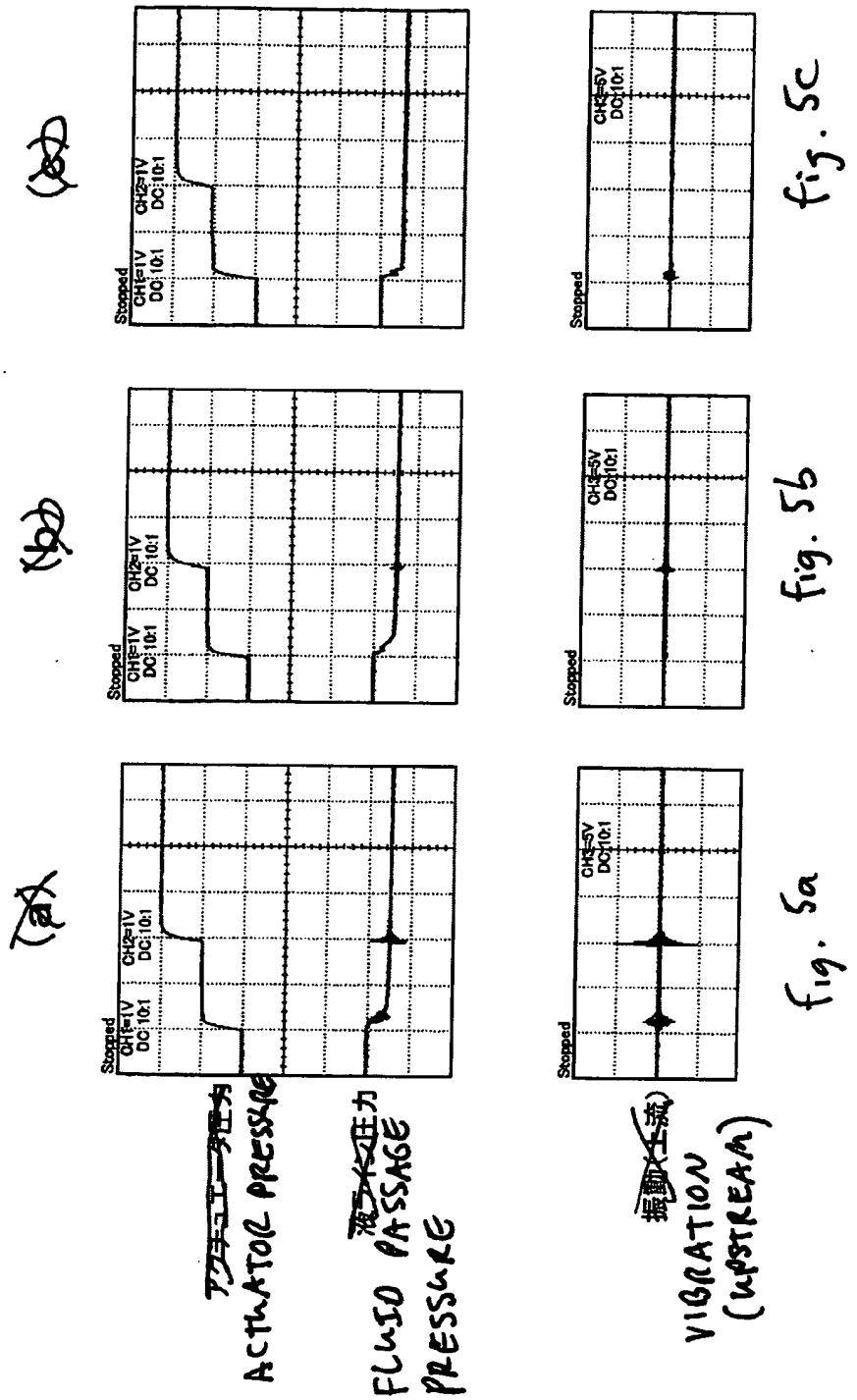
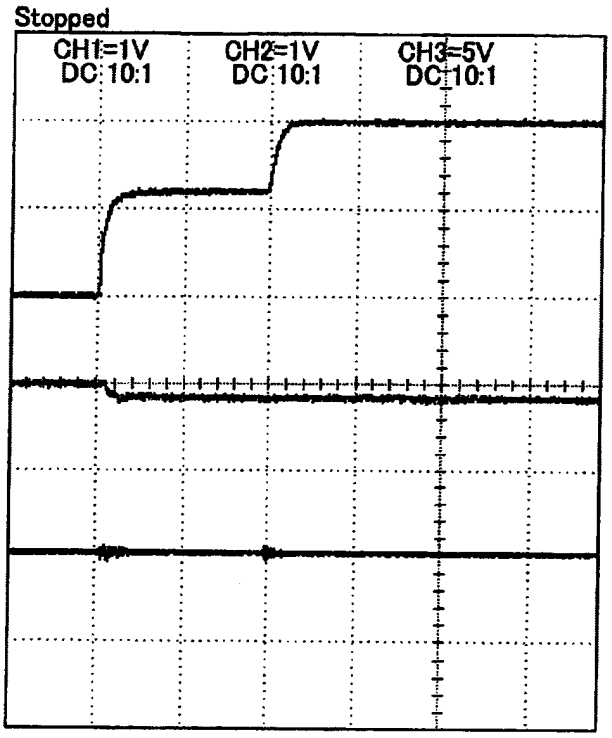


Fig. 5a Fig. 5b Fig. 5c

Annotated

~~図6~~



~~空気圧~~
~~アクチュエータ圧力~~
AIR ACTUATOR PRESSURE

~~液体ライン圧力~~
FLUID PASSAGE PRESSURE

~~配管振動(上流)~~
VIBRATION (UPSTREAM)

Fig. 6

Annotated

TANK PRESSURE
~~タンク圧力~~:0.098MPaG ~~上流振動~~ UPSTREAM VIBRATION

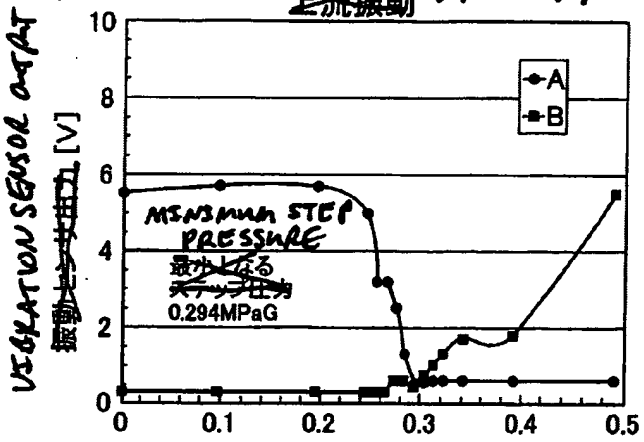


Fig. 7a

TANK PRESSURE ~~タンク圧力~~:0.196MPaG ~~上流振動~~ UPSTREAM VIBRATION

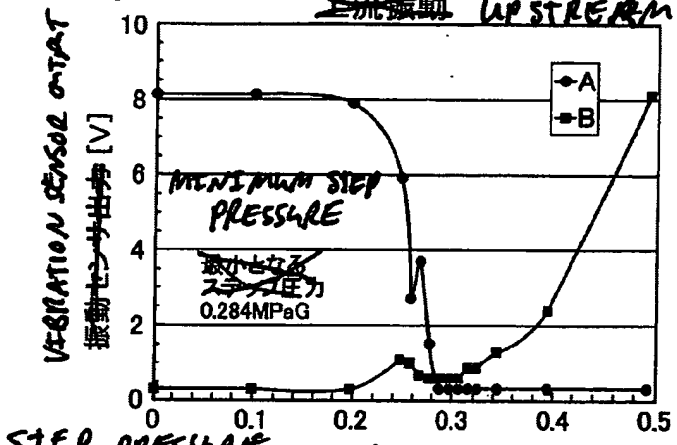


Fig. 7b

TANK PRESSURE ~~タンク圧力~~:0.294MPaG ~~上流振動~~ UPSTREAM VIBRATION

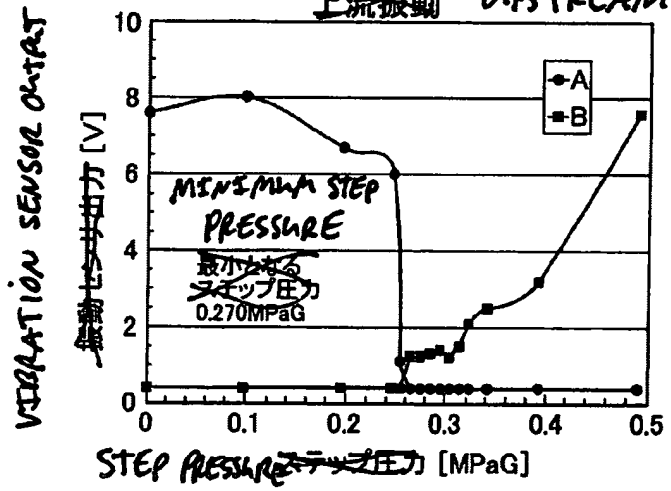


Fig. 7c

Annotated

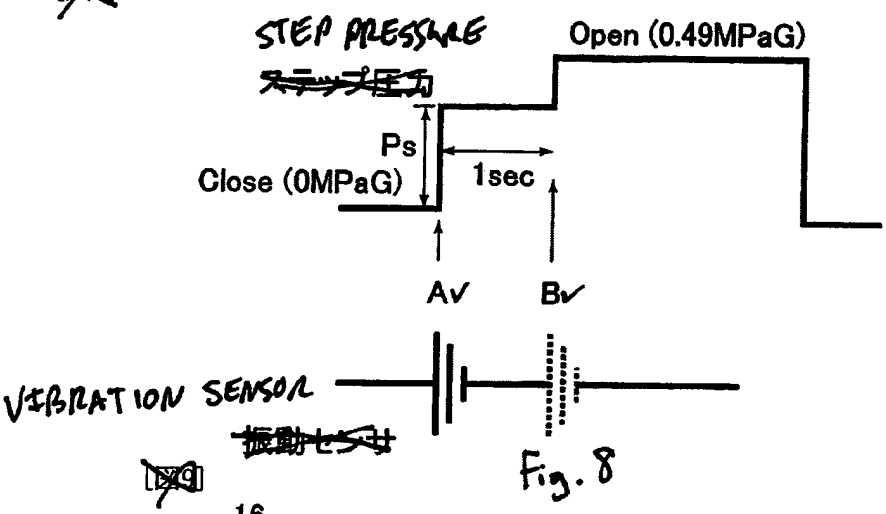


Fig. 8

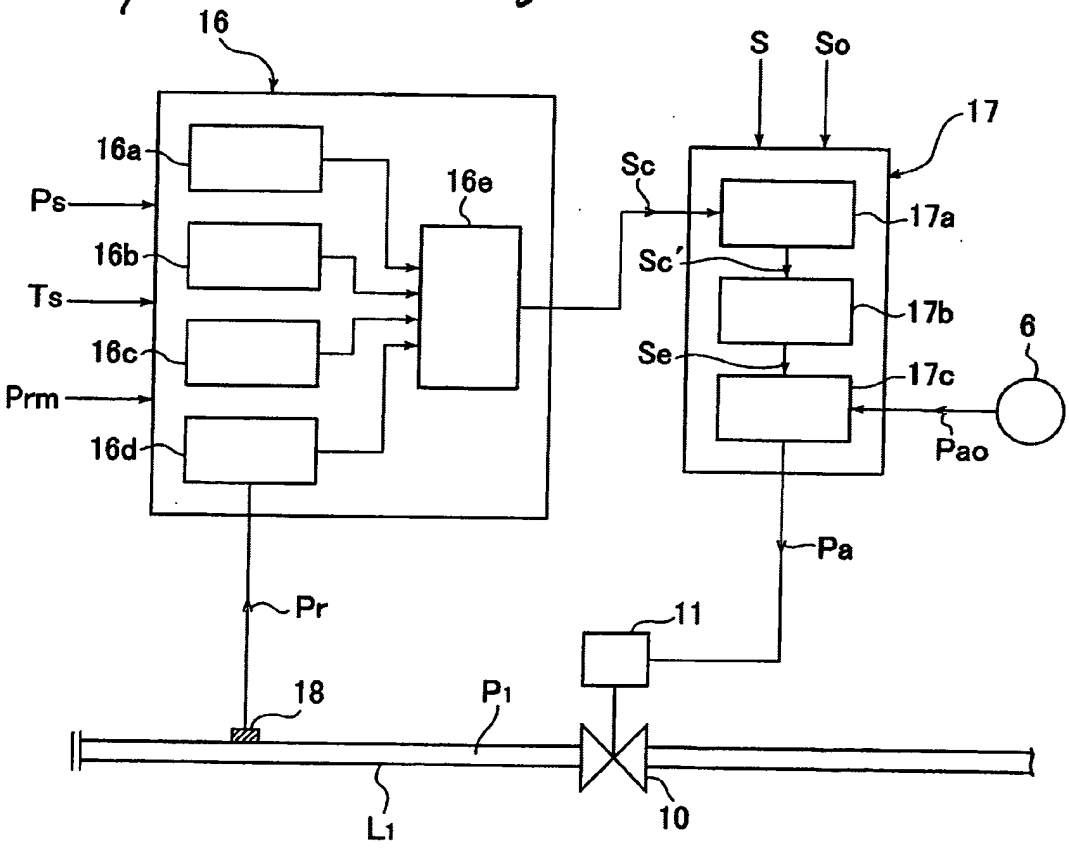


Fig. 9

Annotated

~~[図10]~~

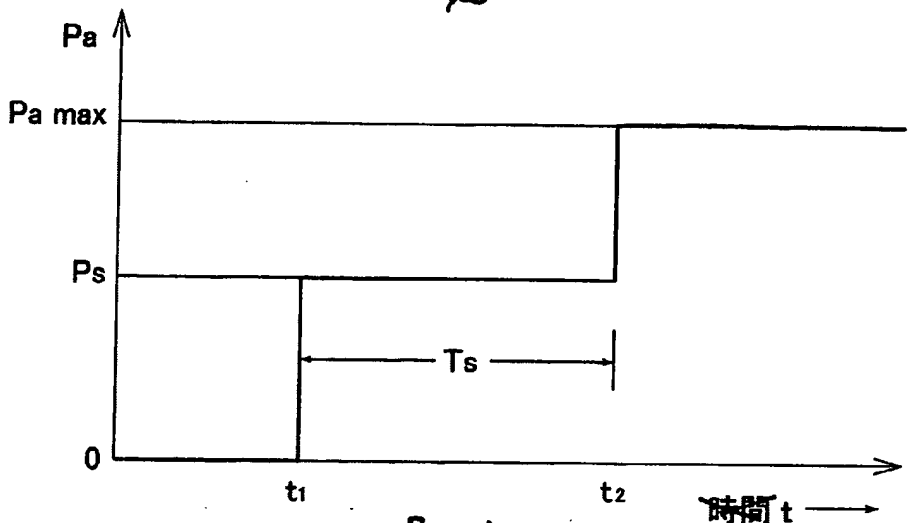


Fig. 10a

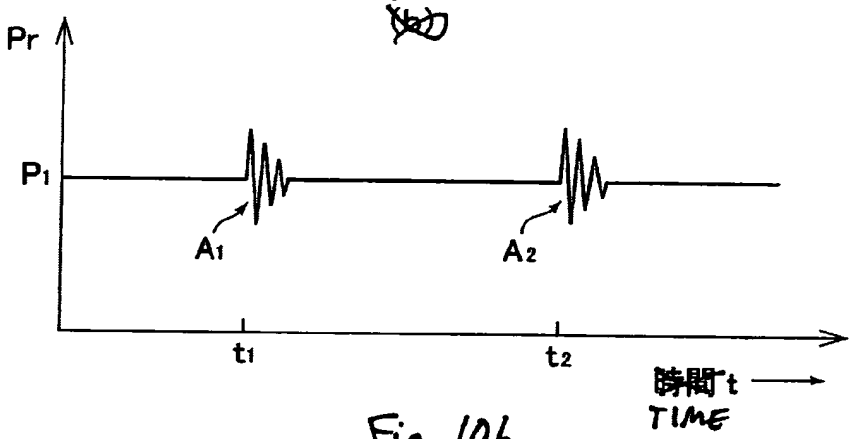


Fig. 10b

Annotated

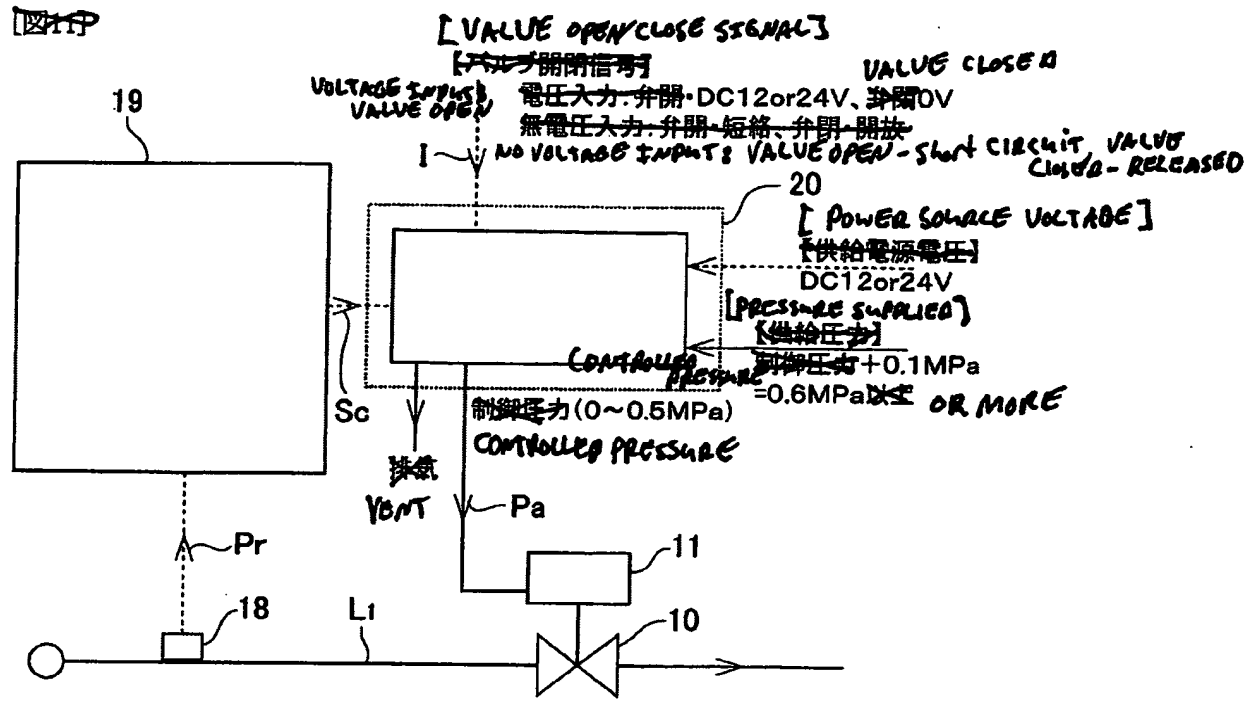


Fig. 12

Annotated

[図13]

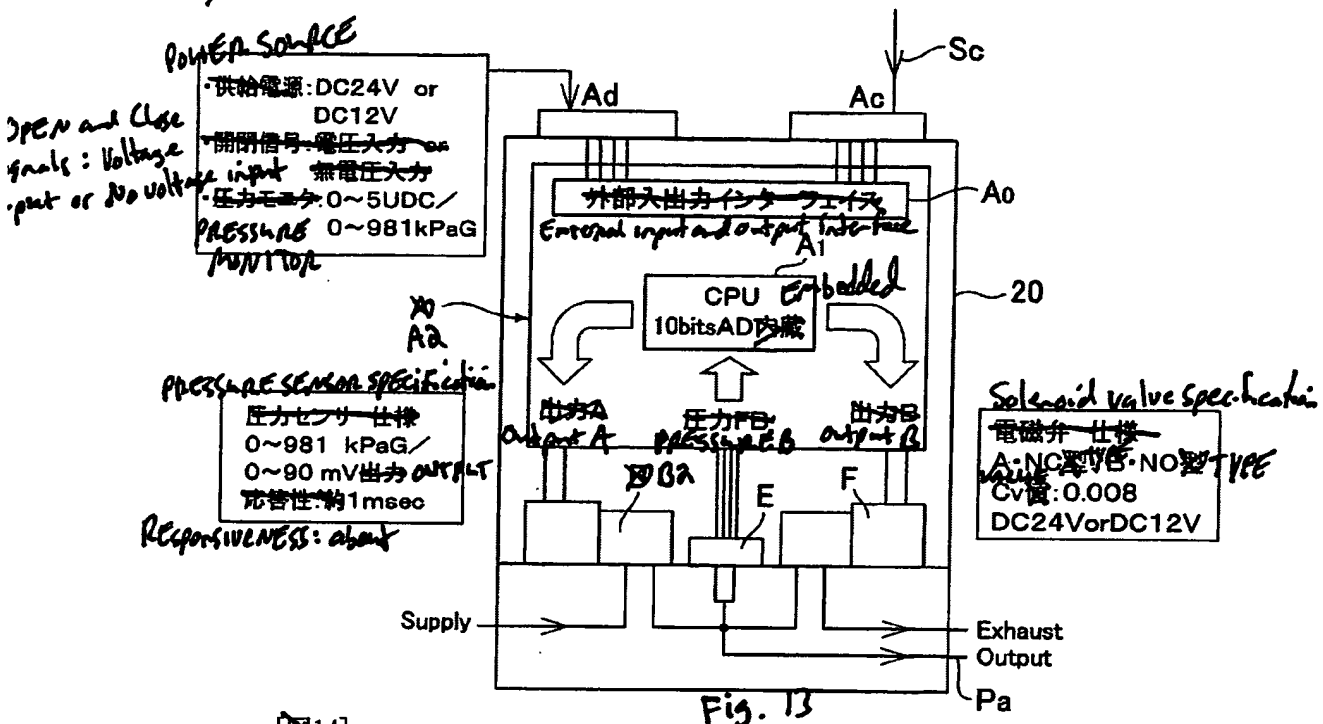


Fig. 13

[図14]

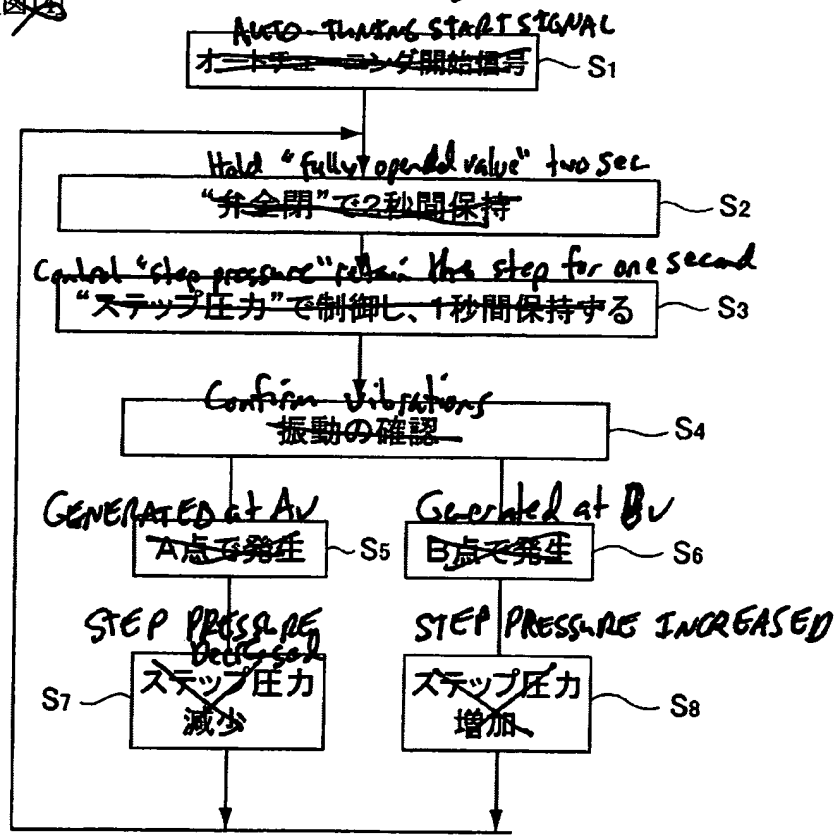


Fig. 14

Annotated

[図15]

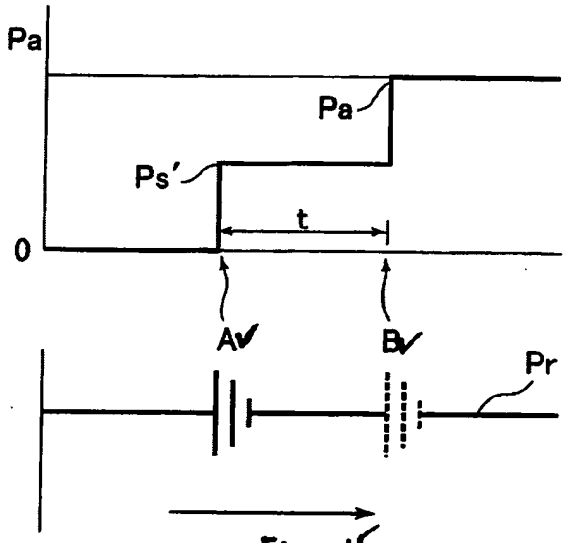


Fig. 15

[図16]

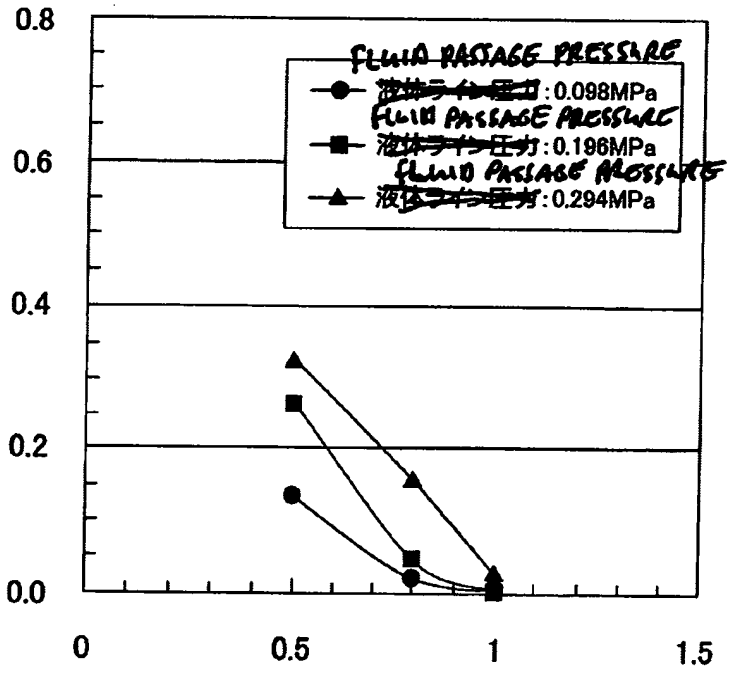


Fig. 16

Annotated

~~[Fig. 17]~~

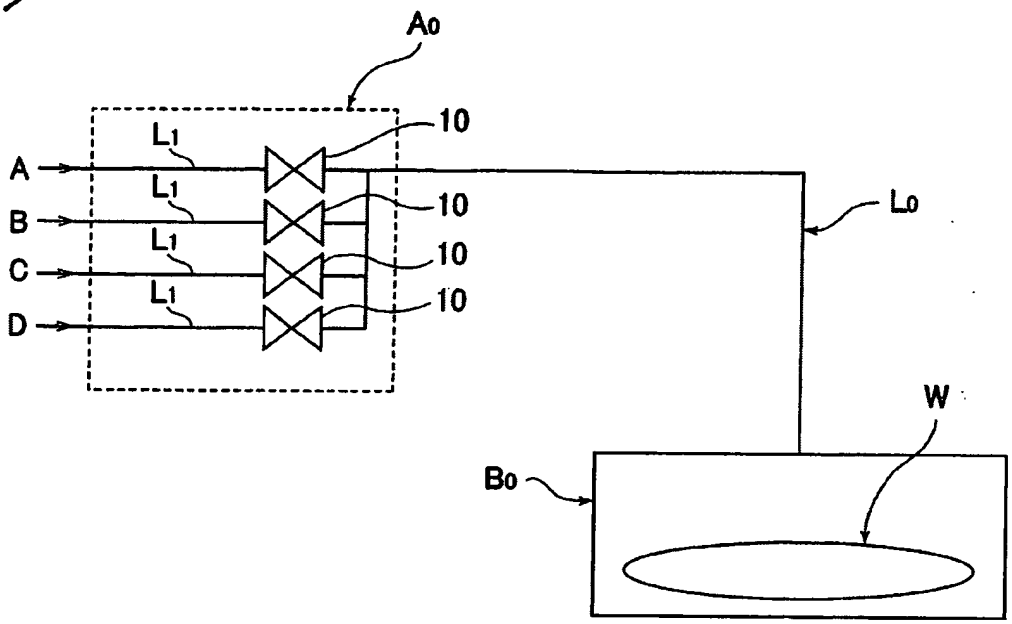


Fig. 17

REMARKS

The specification has been amended to incorporate the International and Japanese priority applications by reference, and to improve grammar, change several character references used in the drawings, and to incorporate certain subject matter contained in the original drawings. A substitute specification in compliance with 37 C.F.R. §1.125 is attached. The attached substitute specification contains no new matter.

The Abstract has been amended to comply with 37 C.F.R. § 1.72. The drawings have been amended to replace Japanese characters with their English equivalents and to comply with 37 C.F.R. § 1.84(p). The claims have been amended to delete multiple dependencies and to place them in better form for examination. The present amendment adds no new matter to the application.

Accordingly, it is believed that the application is in good condition for examination. The below-signed attorney for Applicants welcomes any questions.

Respectfully submitted,

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~~SPECIFICATION~~

METHOD FOR WATER HAMMERLESS OPENING OF FLUID PASSAGE, AND METHOD FOR SUPPLYING CHEMICAL SOLUTIONS AND DEVICE FOR WATER HAMMERLESS OPENING FOR WHICH THE METHOD IS USED

[0000] This is a National Phase Application in the United States of International Patent Application No. PCT/JP2005/000264 filed January 13, 2005, which claims priority on Japanese Patent Application No. 2004-011497, filed January 20, 2004. The entire disclosures of the above patent applications are hereby incorporated by reference.

Field of the Invention

[0001] The present invention is concerned with improvements in a water hammer prevention system with which the water hammer effect is completely prevented when~~at the time of~~ promptly opening ~~of~~ a fluid passage, and is more specifically~~concretely~~ concerned with a method for water hammerless opening of a fluid passage, a method for feeding chemical solutions, and a device for water hammerless opening for which the method is used so that the fluid passage is opened quickly and surely without causing the occurrence of a water hammer effect on the upstream side of the fluid passage irrespective of the degree of the fluid pressure involved.

Background of the Invention

[0002] It has been widely known that when a passage through which a liquid, such as water or the like, passes is abruptly closed, there occurs the so-called water hammer with which the pressure rises inside the passage on the upstream side of the closed point in a vibratory mannerwith vibrations, thereby causingthus various problems such as the breakdown of devices or instruments connected to the passage due to thebeing caused by said water hammer.

[0003] Thus, various techniques have been developed to prevent the occurrence of a water hammer.

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However, these techniques basically employ either one of the following methods, that is: (1) the time for closing a fluid passage isbeing set to be slightly longer, or (2) the vibrating pressure generated inside of the passage isbeing released to the outside by opening athe bypass passage, or isbeing absorbed by a separately installedthe accumulator separately installed. The former method is found to be time-consumingtaking for closing the fluid passage, thus resulting in failure toin meeting with the need forof the prompt closing of the passage, while according to the latter method, the added costs for the bypass passage or the accumulator attachments isbecome too high.

[0004] The afore-mentioned issues regarding the water hammer effect have been discussed in those industrial fields where the fluid involveswith a relatively large flow quantity is involved. In recent years, however, in the fields where a small flow quantity is involveddealt with, for example, in a field where wafer cleaning in semiconductor manufacturing or chemical products manufacturing

are encountereddealt with, it has become a very important to prevent the occurrence of aissue that water hammer is prevented at the time of urgent closure of suppliedthe fluid in order toto be supplied from the view points of improveing the maintenance of facilities, and the improve product quality, and, further, achieve upgrading of so-called throughput characteristics in the manufacturing process.

[0005] Patent Document 1: Toku-Kai-Hei No.7-190235 Public Bulletin

Patent Document 2: Toku-Kai No.2000-10602 Public Bulletin

Patent Document 3: Toku-Kai No.2002-295705 Public Bulletin

[0006] On the other hand, the inventors of the present invention have developed and disclosed techniques to solve the afore-mentioned problems related to conventional techniques forto preventing the occurrence of the water hammer effect, namelythat is, (1) –

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not being able to cope fully with urgent passage closure withoutthe presence of urgency by a measure basically to setting a slightly longer a closing time of the fluid passage slightly longer, and (2) not being able to cope fully with the rising facilities' costs incurredof facilities to be attached by a adding measures that basically to absorb or release the vibrating pressure. T, thus, the present invention makesing it possible to abruptly close athat a fluid passage quickly and surely at low cost andbeing abruptly closed without generating a water hammer at a low cost, quickly and surely.

In particularNamely, thesaid techniques of the present invention allow a fluid passage to be abruptly closed without the occurrence of a water hammer

and, in an extremely short lapse of time (for example, within 1000 m-sec), by performing ~~the~~ closure of a valve provided on the fluid passage by means of ~~the~~ multi-step closing operations. Also, ~~the~~said techniques of the present invention determine the conditions for closing ~~the~~a valve in advance of actual closure, and in order to make it possible for the fluid passage to ~~be~~ closed without a water hammer forming, ~~in advance~~ by actually conducting valve closing tests so that the actuator of the valve body is operated by ~~an~~the electro-pneumatic conversion device in which ~~said~~ valve closing conditions are stored. ~~,~~ Tthus, water hammerless closing of the fluid passage is~~being~~ achieved quickly and surely.

~~Disclosure of the Invention~~

Object of the Invention

[0007] W~~Techniques of w~~ater hammerless closing techniques for~~of~~ a fluid passage have previously been developed by inventors of the present invention and allow the fluid passage to be abruptly closed, quickly and surely, without causing a water hammer effect ~~quickly and surely~~, thus achieving excellent, practical effects.

[0008] ~~———~~However, in recent years, in ~~the~~ fields such as the semiconductor –

~~3~~

manufacturing facility industry, the chemical and pharmaceutical industries, and the like, there ~~has~~have been a strongly desired to reliably prevent the~~that~~ water hammer effect at the time when the fluid passage is abruptly opened and~~is~~

surely prevented not only at the time when the fluid passage is abruptly closed, but also at the time when the fluid passage is abruptly opened. This means that the conventional measure forof preventing a water hammer at the time of abrupt closure of the fluid passage has not beenis found not to be sufficient. The reason is that when a water hammer occurs at the time of opening the fluid passage, various difficulties, such as moving of particles into the fluid passage and the like, arisecome up.

[0009] Due to the recent trend whereinthat the semiconductor cleaning devices, and the like, employ the cleaning equipment with which wafers are now treated one by one (a single wafer processing cleaner), it has become an important issue not only that quality improvements in thea liquid supply system are achieved, but also that the time required for each process of cleaning is shortened to improve so-called throughput characteristics. Furthermore, with use of the afore-mentioned new treatment-type semiconductor manufacturing facility, it becomes inevitable that the frequency of valves opening being opened and closingclosed increases because wafers are singly treated singly. Therefore, there is a need for stable or water hammerless valve opening and closing methodsare needed. As such, it has become a strictsevere requirement that athe liquid supply system does not cause pressure fluctuations while wafers are processed.

[001008] It is an object of the present invention to solve the afore-mentioned problems encountered with semiconductor manufacturing facilities, cleaning equipment and the like, and to provide a method for water hammerless opening of athe fluid passage, and a method for the supply of liquid, supply and a device

for water hammerless_–

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opening, for which the method is used so that the fluid supply passage is surely and abruptly opened in a state of water hammerlessness.

Summary of the Invention~~Means to Achieve the Object~~

[0011~~09~~] Inventors of the present invention have conceived~~come up with an idea~~ of how to open a valve by a~~the~~ multi-step method, in which a valve body of the valve blocking the passage is rapidly moved to a~~the~~ prescribed position before reaching the full opening position, and then, the valve body is moved to the full opening position after a~~the~~ short lapse of time. A~~, and~~ at the same time, a number of analytical tests were conducted by the inventors on the mechanism of how a water hammer occurs by employing~~using~~ the~~said~~ method of the present invention for opening the valve. F~~Also, rom~~with the results of the afore-mentioned tests, the inventors of the present invention have learned how to prevent the occurrence of the water hammer effect by making the stopping position of the valve body at a~~the~~ first step come within a~~the~~ specified range when the valve is first opened.

[0012~~0~~] The present invention has been created based on the afore-mentioned findings. The present invention, in accordance with a first method embodiment~~as claimed in Claim 1~~, is fundamentally ~~so~~ constituted so that, with the method by which the fluid passage is made open by means of the actuator operating type valve provided on the fluid passage having a~~the~~ nearly constant pressure inside the pipe passage, first the valve body is moved toward the

direction of the valve opening by increasing or decreasing to the prescribed set value the afore-mentioned driving input to the actuator ~~being increased or reduced to the prescribed set value~~, and the driving input to the actuator is held at the afore-mentioned set value for a short period of time, and then, the~~said~~ driving input is further increased or reduced ~~,~~

~~5~~

to place~~make~~ the valve in a state of full opening, thus the fluid passage is~~being~~ opened without causing a water hammer.

[0013~~1~~] The present invention in accordance with a second method embodiment, which further modifies the first method embodiment,~~as claimed in Claim 2 according to Claim 1~~ is ~~so~~ made so that the valve is a normally closed and pneumatic pressure operating type diaphragm valve, or a normally closed and pneumatic pressure operating type diaphragm valve which is of the fixed capacity type with the inner capacity of the valve not changing~~being changed~~ when the valve is operated~~, is employed for a valve~~.

[0014~~2~~] The present invention in accordance with a third method embodiment, which further modifies the first method embodiment,~~as claimed in Claim 3 according to Claim 1~~ is ~~so~~ made so that the time for holding the driving input to the actuator ~~being held~~ at the set value for a short period of time is made to be less than 1 second, and the pressure rise value of the fluid passage is made to be within 10% of the pressure value before the valve is made to open.

[0015~~3~~] The present invention in accordance with a first apparatus embodiment~~as claimed in Claim 4~~ is fundamentally ~~so~~ constituted so that a device for water hammerless opening of a fluid passage~~it~~ comprises a valve

body, an actuator to drive the valve body, a vibration sensor removably fixed to the pipe passage on the upstream side of the valve body, an electro-pneumatic conversion control device to which athe valve opening/closing command signal is inputted and with which the actuator operating pressure Pa inputted to the actuator is controlled by athe control signal Sc stored in athe data storage part in advance, and a computation control device equipped with a comparison computation circuit to which athe vibration detecting signal Pr from the afore-mentioned vibration sensor, athe step pressure setting signal Ps to be supplied to the actuator, athe step pressure holding time setting signal Ts, and athe permissible upper limit vibration pressure setting signal Prm_-

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are inputted, and with which the afore-mentioned vibration detecting signal Pr and the permissible upper limit vibration pressure setting signal Prm are compared, and the afore-mentioned step pressure setting signal is adjusted, thus outputting the control signal Sc consisting of the afore-mentioned holding time setting signal Ts and adjusted step pressure setting signal Ps to the data storage part of the afore-mentioned electro-pneumatic conversion control device.

[00164] The present invention in accordance with a second apparatus embodiment, which further modifies the first apparatus embodiment,as claimed in Claim 5 according to Claim 4 is co constituted so that thea computation control device comprises a step pressure setting circuit, a holding time setting circuit, a permissible upper limit vibration pressure setting circuit, a vibration pressure detecting circuit and a comparison computation circuit; and, when the vibration

detecting signal Pr exceeds the permissible upper limit vibration pressure setting signal Prm immediately after the actuator operating signal is step-changed, the step pressure setting signal Ps is adjusted toward the rising direction, and when the vibration detecting signal Pr exceeds the permissible upper limit vibration pressure setting signal Prm immediately after the actuator operating pressure is made to zero from the intermediate step operating pressure, the step pressure setting signal Ps is adjusted toward the lowering direction.

[00175] The present invention in accordance with a third apparatus embodiment, which further modifies the first apparatus embodiment,~~as claimed in Claim 6 according to Claim 4~~ is ~~so~~ constituted so that an electro-pneumatic conversion device comprises a data storage part that~~which~~ stores the control signal Sc from the computation control device, a signal conversion part and an electro-pneumatic conversion part; the

~~7~~

actuator operating pressure control signal Se is outputted from the signal conversion part to the electro-pneumatic conversion part based on the control signal Sc' stored in the data storage part in advance so that~~with which~~ no water hammer is caused.

[00186] The present invention in accordance with a fourth apparatus embodiment~~as claimed in Claim 7~~ is fundamentally ~~so~~ constituted so that a device for water hammerless opening of a fluid passage~~it~~ comprises an actuator operating type valve installed on the fluid passage, an electro-pneumatic conversion device to supply ~~a~~the 2-step actuator operating pressure Pa to the actuator operating type valve, a vibration sensor removably fixed to the pipe

passage on the upstream side of the afore-mentioned actuator operating type valve, and a tuning box to which the vibration detecting signal Pr detected through the vibration sensor is inputted, and from which the control signal Sc is outputted to the electro-pneumatic conversion device to control the step operating pressure Ps' of the afore-mentioned 2-step actuator operating pressure Pa ~~is outputted to the electro-pneumatic conversion device~~, and to output the 2-step actuator operating pressure Pa of the step operating pressure Ps', which makes the vibration detecting signal Pr nearly zero, from the electro-pneumatic conversion device by adjusting said control signal Sc.

[0019~~7~~] The present invention in accordance with a fourth method embodiment~~as claimed in Claim 8~~ is fundamentally ~~so~~ constituted so that, with the method for opening a fluid passage for which a vibration sensor is removably fixed on the upstream side of the actuator operating type valve installed on the fluid passage, and the vibration detecting signal Pr is inputted to the tuning box, and then, the control signal Sc from the tuning box is inputted to the electro-pneumatic conversion device, thus the

~~8~~

2-step actuator operating pressure Pa generated in the electro-pneumatic conversion device by the afore-mentioned control signal Sc is~~being~~ supplied to the actuator so that the actuator operating type valve is made to open in the 2-step operation, the 2-step actuator operating pressure Pa ~~to be~~ supplied to the actuator and the vibration detecting signal Pr are compared for the relative relation of the two, and if ~~the~~ vibration is generated at the time when the first step actuator operating pressure Pa rises, the step operating pressure Ps' is lowered,

and if ~~the~~ vibration is generated at the time when the second step actuator operating pressure Pa rises, the step operating pressure Ps' is raised, and the step operating pressure Ps'$_1$ of the step operating pressure Pa to make the vibration detecting signal Pr nearly zero$_1$ is determined by repeating a plurality ~~number~~ of adjustments of raising or lowering the afore-mentioned step operating pressure Ps' so that the afore-mentioned actuator operating type valve is opened~~made open~~ based on ~~the~~ data on the control signal Sc when the 2-step operating pressure Pa of the step operating pressure Ps' is outputted from the electro-pneumatic conversion device to make ~~the~~ generation of ~~said~~ vibration nearly zero ~~is outputted from the electro-pneumatic conversion device~~.

[002~~018~~] The present invention in accordance with a fifth method embodiment~~as claimed in Claim 9~~ is fundamentally ~~so~~ constituted so that, using~~with~~ the method for opening a fluid passage for which a vibration sensor is removably fixed on the upstream side of the actuator operating type valve installed on the fluid passage, ~~and~~ the vibration detecting signal Pr is inputted to the tuning box, and then, the control signal Sc from the tuning box is inputted to the electro-pneumatic conversion device. T~~,~~ thus, the 2-step actuator operating pressure Pr generated by~~in~~ the electro-pneumatic

~~9~~

conversion device by the afore-mentioned control signal Sc ~~being~~ is supplied to the actuator so that the actuator operating type valve is made to open in the 2-step operation, and the 2-step actuator operating pressure Pa ~~to be~~ supplied to the actuator and the vibration detecting signal Pr are compared for the relative relation of the two, and if ~~the~~ vibration is generated at the time when the first step

actuator operating pressure Pa drops, then the step operating pressure Ps' is raised, and if ~~the~~ vibration is generated at the time when the second step actuator operating pressure Pa drops, then the step operating pressure Ps' is lowered, and the step operating pressure Ps' of the step operating pressure Pa is determined to make the vibration detecting signal Pr nearly zero ~~is determined~~ by repeating a plurality ~~number~~ of adjustments of raising or lowering of the afore-mentioned step operating pressure Ps' so that the afore-mentioned actuator operating type valve is ~~made~~ opened based on ~~the~~ data on the control signal Sc when the 2-step operating pressure Pa of the step operating pressure Ps' is outputted from the electro-pneumatic conversion device to make the generation of ~~said~~ vibration nearly zero ~~is outputted from the electro-pneumatic conversion device~~.

[0021~~10~~] The present invention in accordance with a sixth method embodiment, which further modifies the fourth and fifth method embodiments, ~~as claimed in Claim 10 according to Claim 8 or Claim 9~~ is ~~so~~ made so that the vibration sensor and tuning box can be removed after ~~the~~ data on the control signal Sc_1 at the time of outputting the 2-step operating pressure Pa with which ~~the~~ generation of vibration is nearly zero, arewere inputted to the memory storage of the electro-pneumatic conversion device.

[0022~~0~~] The present invention in accordance with a seventh method embodiment, which further modifies the fourth and fifth method embodiments, ~~as claimed in Claim 11 according to Claim 8 or Claim 9~~ is ~~so~~ made so that the vibration sensor is provided at ~~a~~the position on the upstream side within 1000mm from the place where the actuator operating type –

valve is installed.

[00234] The present invention in accordance with an eighth method embodiment, which further modifies the fourth and fifth method embodiments,~~as claimed in Claim 12 according to Claim 8 or Claim 9~~ is ~~so~~ made so that the step operating pressure holding time t of the 2-step operating pressure Pa is set at less than 1 second.

[00242] The present invention in accordance with a ninth method embodiment~~as claimed in Claim 13~~ is ~~so~~ made so that, employing~~with~~ the method with which a fluid is supplied to the fluid passage on the downstream side by opening the fluid passage by means of the actuator operating type valve installed on the fluid passage and having a nearly constant internal pressure therein, a chemical solution is used for ~~a~~ fluid, and ~~firstly~~, the valve body is moved toward ~~the~~ direction of ~~the~~ valve opening by increasing or decreasing the afore-mentioned driving input to the actuator to the prescribed set value, and the actuator driving input is held at the afore-mentioned set value for a short period of time, and second~~then~~, the~~said~~ driving input is further increased or decreased to make the valve in a state of full opening so that a water hammer does not occur at the time ~~of~~ the valve is~~being~~ opened.

[00253] The present invention as claimed in Claim 14 according to Claim 13 is ~~so~~ made so that the time the actuator driving input is to be held at the set value ~~for a short period of time~~ is made to be less than 1 second, and the pressure rise value of the fluid passage is made to be within 10% of the pressure value before the valve is ~~made~~ opened.

Effects of the Invention

[00264] EmployingWith the method of the present invention, it is made possible to abruptly openthat a fluid passage is abruptly opened in an extremely short period of time (e.g., within 300~1000m sec.) and without causing a water hammer because the valve can be –

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opened in athe manner that, in the case wherethe fluid pressure is constant, the driving force to the actuator is held at the set value, to move the valve body to the prescribed position and to halt once for a short period of time. Then to halt, and then, the valve body is moved to the full opening position, thus making the set value for the afore-mentioned driving force athe value in the appropriate range.

[00275] TWith the water hammerless opening device, according to the present invention, it is so constituted so that water hammerless valve opening is achieved by a vibration sensor 18 that isbeing removably fixed to the pipe passage L_1, wherein the vibration detecting signal Pr is detected by the vibration sensor 18 and isbeing fed back to the computation control device 16, and the actuator operating pressure to be applied to the actuator 11 of the valve body 10 is controlled through the mediation of the electro-pneumatic conversion control device 17 being controlled.

As a result, without there being a stroke position detecting device being installed on the valve body 10, or without athe pressure detector being left attached to the pipe passage L_1, water hammerless opening can be achieved,

and once the optimum conditions on water hammerless valve opening (that is, the conditions on the control of the actuator operating pressure Pa) for the subjected pipe passage L_1 is determined, the vibration sensor 18 and computation control device 16 can be removed so that they can be used for other pipe passages, thus making it extremely advantageous economically.

[00286] Furthermore, in accordance with the water hammerless opening device for the fluid passage ofaccording to the present invention, it is so made that a vibration sensor 18 is installed in the vicinity of the valve body 10 on the pipe passage under an the –

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actual operating condition, and the valve body 10 is actually operated for opening/closing by applying the prescribed 2-step actuator operating pressure Pa to the actuator 11 of the valve body 10 from the electro-pneumatic conversion device 20 so that anthe optimum value of the step operating pressure Ps' of the afore-mentioned 2-step actuator operating pressure Pa is determined through the actual operation of the valve body 10, and the determined actuator operating pressure Pa is stored byat the storage device of the electro-pneumatic conversion device 20.

As a result, It is makes possible to abruptly openthat the valve body 10 both reliablyis abruptly opened surely and promptly and without causing a water hammer on the fluid passage by usingwith the actuator operating pressure Pa offrom the electro-pneumatic conversion device 20.

[00297] In addition, the selection and setting (tuning) of the afore-mentioned 2-step actuator operating pressure Pa can be easily performed through the

actual operations of the valve body 10 over 5~6 times. Also, by applying the actuator operating pressure Pa_1 having the appropriate step operating pressure Ps'_1 to the actuator 11, the value in amplitude of the pressure vibration at the time of the valve body 10 is being actually opened for the first time can be suppressed to at the lower value, thus making it possible to accurately determine in advance what is that the optimum value of the afore-mentioned actuator operating pressure Pa is determined accurately in advance without adversely affecting the pipe passage being adversely affected.

[003028] Furthermore, by utilizing a personal computer, it is becomes possible to perform that the selection and setting (tuning) of the afore-mentioned 2-step actuator –

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operating pressure Pa both is performed extremely easily at ease and promptly, and also so that the water hammerless opening device is manufactured at lower cost.

Brief Description of Drawings

[003129] Figure 1 is a circuit diagram of the testing device used for detecting the occurrence of a water hammer on the fluid passage.

[0032] Figure 2 is an explanatory drawing to illustrate an electro-pneumatic conversion device used for the testing device, wherein (a) is a basic block diagram, and (b) is a block diagram.

[0033] Figure 3 is a graph diagram to illustrating the relationship between an input signal I (input voltage V) and an output pressure Pa (kgf/cm · G) of the

electro-pneumatic conversion device 5.

[0034] Figure 4 is a graphdiagram to illustratinge, with the multi-step opening in which the internal pressure P_1 of the pipe passage 1 is made constant, and to illustrate thea state of vibration changes in the pipe passage L_1 on the upstream side of the valve in the case where the supply pressure Pa to the actuator is made changed, wherein (a) shows the case where Pa is opened directly from 0kgf/cm · G to 5kgf/cm · G, and (b) shows the case where Pa is changeddropped from 0kgf/cm · G to 3.1kgf/cm · G and then to 5.0kgf/cm · G0.

[0035] Figure 5 is a graphdiagram to illustratinge how the internal pressure P_1 of the pipe passage changes at the multi-step type opening (Pa=0→=2.5=→5kgf/cm · G) in the case wherethe tank pressure (the internal pressure P_1 of the pipe passage) is made to changed, wherein (a) shows the case where the internal pressure P_1 of the tank = 0.245MPa · G, (b) P_1 = 0.255 and (c) P_1 = 0.274 respectively.

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[0036] Figure 6 is an enlarged view of Figure 5(c).

[0037] Figure 7 is a graphdiagram to illustratinge the relationship between the internal pressure PT of the tank and the actuator operating pressure Pa so as to prevent a water hammer usingwith the multi-step valve closing, wherein (a) shows the case where the internal pressure of the tank = 0.098MPaG, (b) 0.196MPaG and (c) 0.294MpaG, respectively.

[0038] Figure 8 is an explanatory drawing to illustratinge the relationship between the actuator operating pressure Pa and the time of detecting the vibration in Figure 7.

[0039] Figure 9 is a whole block diagram of athe first embodiment of the water hammerless opening device for the fluid passage according to the present invention.

[0040] Figure 10 is an explanatory drawing to illustratinge the control of the actuator operating pressure Pa (Figure 10a) and one example of the occurrence of the vibration (Figure10b) usingwith the water hammerless opening device ofin Figure 9.

[0041] Figure 11 is a whole system diagram of the water hammerless opening device with respectin regard to athe second embodiment according to the present invention.

[0042] Figure 12 is an overview of athe PC screen display of a tuning box.

[0043] Figure 13 is a schematic block—schematic diagram of an electro-pneumatic conversion device.

[0044] Figure 14 is a flow chart of auto-tuning operations.

[0045] Figure 15 is an explanatory drawing for the relationship between the driving –

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pressure Pa and the vibration that occurred in the auto-tuning operations.

[0046] Figure 16 is a graphdiagram to illustratinge the relationship between the step pressure holding time t of the driving pressure Pa in steps and the pressure rising value $\triangle P$.

[0047] Figure 17 is a system diagram to illustratinge the case wherethat the chemical solution supply method according to the present invention is applied to athe single wafer processing cleaner of the semiconductor manufacturing

equipment.

List of Reference Characters and Numerals

[004~~830~~] PT Internal pressure of a water tank

L_1 Pipe passage on the upstream side of a valve

P_1 Internal pressure of a pipe passage

Pa Actuator operating pressure

Pao Air supplying pressure

$\triangle G$ Valve stroke

S Valve opening/closing command signal

1 Water tank

2 Source for pressurizing a water tank

3 Pressure sensor

4 Valve

4a Actuator

5 Electro-pneumatic conversion device

6 Valve driving gas source

7 Signal generator

~~16~~

8 Storage oscilloscope

10 Valve body

11 Actuator

16 Computation control device

17 Electro-pneumatic conversion control device

18 Vibration sensor

19 Tuning box

20 Electro-pneumatic conversion device

T Opening time detecting signal

P_1 Pressure detecting signal

PM Permissible pressure rising value setting signal

Pr Vibration detecting signal

Prm Permissible upper limit vibration pressure setting signal

Ps Step pressure setting signal

Ts Step pressure holding time setting signal

(Opening time setting signal)

Sc Control signal

Se Actuator operating pressure control signal

So NO-NC switching signal for a valve

t Step pressure holding time

Ps' Step operating pressure

A_0 Fluid supply system

B_0 Single wafer processing cleaner

~~17~~

W Wafer

A · B · C · D Chemical solutions to be mixed

Detailed Description of the Invention~~Practice of the Invention~~

[004~~9~~31] In order to investigate how a water hammer is caused in the liquid

supply system of ~~the~~ semiconductor manufacturing equipment, the inventors of the present invention have observed ~~the~~ pressure changes in the fluid flow passage at the time when the flow passage is switched from ~~the~~ full closing to ~~the~~ full opening by employing a pneumatic pressure operating diaphragm.

Figure 1 is a circuit diagram of the testing device employed for the afore-mentioned investigation. Referring to Figure 1, 1 designates a water tank, 2 is a source for pressurizing the water tank, 3 is a pressure sensor, 4 is a valve, 5 is an electro-pneumatic conversion device, 6 is a valve driving gas source, 7 is a signal generator and 8 is a storage oscilloscope.

[005~~32~~] The afore-mentioned water tank 1, having a capacity of 30 liters, is ~~of~~ a hermetically sealed structure and stores about 25 liters of the fluid (water of 25℃) therein.

Also, the water tank 1 is pressurized by N_2 from the pressurizing source 2, and the pressurization can be adjusted~~able~~ as desired within the range of 100~300KPaG.

[005~~133~~] The afore-mentioned pressure sensor 3 is capable of detecting water pressure on the upstream side of the valve 4 with high sensitivity. A diffusion semiconductor type pressure sensor is~~was~~ employed in the testing device.

[005~~234~~] A diaphragm type pneumatic valve is used for the afore-mentioned ~~18~~ valve 4, and specifications thereof are as follows: fluid inlet pressure 0.1MPa, fluid outlet pressure 0.3MPa, fluid temperature 10~100℃, the CV value 0.27, operating air pressure 3~0.6MPa, materials of liquid-contacting parts (PTFE for the valve body and PTFE for the diaphragm), and the inside diameter of the

passage is 4mm.

~~———~~Specifically~~Namely~~, the~~said~~ valve 4 is a pneumatically operating diaphragm valve whose~~ich~~ valve body is a normally-closed (N.C.) type synthetic resin made diaphragm. The diaphragm valve body rests~~is rested~~ on the valve seat all of the time due to~~by~~ the elastic force of a~~the~~ spring (not shown in the figure) so that the valve is maintained in a closed state. W~~,~~ while the actuator 4a is operated by~~with~~ the supply of ~~the~~ operating pneumatic pressure, the~~us~~ result~~ing~~ is~~n~~ ~~that~~ the diaphragm valve body moving~~is moved~~ away from the valve seat and maintaining a~~maintained in a~~ state in which the valve is kept open.

~~———~~Accordingly, to open the~~said~~ normally-closed type pneumatically operating type diaphragm valve, it is required that ~~the~~ operating pneumatic pressure be~~is~~ supplied to the actuator 4a.

~~———~~According to the present invention, it goes without saying~~there is no need to say~~ that a normally-closed type pneumatically operating diaphragm valve can be replaced by a normally-open (N.O.) type pneumatically operating diaphragm valve. In such a~~this~~ case, the normally-open type valve is maintained in a state of being closed by raising the operating pneumatic pressure ~~to be~~ supplied to the actuator 4a.

[005~~335~~] The afore~~-~~mentioned electro-pneumatic conversion device 5 is used to supply driving pressure (pneumatic pressure), corresponding to the input signal ~~-~~

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for directing the degree of ~~the~~ valve opening, to the actuator 4a for the valve 4. As part of~~With~~ the testing device of Figure 1, the electro-pneumatic conversion

device 5, which is constituted as shown in Figure 2, ~~is~~has been employed.

In particular~~Namely~~, when the input signal I is inputted to the control circuit A2, an air supply electromagnetic valve B2 opens so that a part of the supply pressure C2 is supplied to the actuator 4a ~~of~~for the valve 4 as an output pressure Pa through the air supply electromagnetic valve B2.

The output pressure Pa is fed back to the control circuit A2 through the mediation of the pressure sensor E, thus an~~the~~ operations for correction is ~~being~~ effected until the outputted pressure Pa reaches the output pressure Pa corresponding to the input signal I. Referring to Figure 2, F designates an exhaust electromagnetic valve, G is an exhaust, H is a power source, and J is an output signal corresponding to the input signal I. The~~Said~~ output signal J (that is, an input signal I) is inputted to the storage oscilloscope 8 as the input voltage as described later.

[0054~~36~~] Figure 3 is a diagram ~~to~~ illustrating the relationship between the value of the input signal I (input voltage V) of the afore-mentioned electro-pneumatic conversion device 5 and the output pressure Pa. Figure 3~~It~~ shows that the valve 4 is held in a state of full opening when~~with~~ the input voltage is 5V (operating air pressure P = approximately 5kgf/cm · G).

[0055~~37~~] A compressor is employed for the afore-mentioned valve operating air source 6 to supply gas~~air~~ with the prescribed pressure. And, the afore-mentioned signal generator 7 generates the input signal I, and the like, to the

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electro-pneumatic conversion device 5, and the like, so that the desired voltage

output is outputted to the electro-pneumatic conversion device 5 as the input signal I.

Furthermore, the pressure detecting signal P_1 (voltage V), in the pipe passage L_1 on the upstream side from the pressure sensor 3, and the input signal I (input voltage V) to the electro-pneumatic conversion device 5 are inputted to the afore-mentioned storage oscilloscope 8 in order to observe and record the changes in the pressure P_1 in the pipe passage L_1, the changes in the input signal (input voltage V), and the like. The storage oscilloscope 8, which has its time-axis ~~is~~ graduated in 500m sec/1, is~~has been~~ employed in~~for~~ the testing device.

[005~~6~~38] Referring to Figure 1, the internal pressure PT of the water tank 1 is held at a specified pressure of 0.172MPa · G, and the operating~~air~~ pressure Pa of 0.490MPa · G is supplied to the actuator 4a, thus making the valve 4 move to a state of full opening from a state of full closing. In this case~~Here~~, the inside diameter of the pipe passage L_1 was 4.0mm, the length approximately 1.0m, and the flow rate Q of ~~the~~ water was approximately 3.45 liters/min. Figure 4 shows changes in the supply air pressure Pa to the actuator 4a ~~offer~~ the valve 4 and in the internal pressure P_1 of the pipe passage L_1 on the upstream side observed by the storage oscilloscope.

As apparent from ~~the afore shown~~ Figure 4(a), ~~there were shown~~ changes in ~~the~~ vibration output, with the amplitude of approximately maximum 12V, were shown ~~as in Figure 4(a)~~ when the valve 4 was fully opened through the process of 0 (fully closed)→0.490MPa · G (fully opened).

[005~~7~~39] On the other hand~~contrary~~, in the case where~~the~~ supply pressure Pa

is made to changed as 0 (fully closed)

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→0.29 MPa · G (mid-position or intermediate position)→0.490 MPa · G (fully opened) (Figure 4(b)), ~~there were seen~~ nearly no changes in the vibration of the pipe passage were observed, thus demonstrating~~resulting in~~ that the water hammer effect can be ~~is~~ perfectly prevented.

[005~~840~~] In particular~~Namely~~, it is apparent that~~,~~ if the internal pressure P_1 of the pipe passage L_1 is kept constant, then (1) the fluid passage can be opened, without causing a water hammer, in about 500~1000m sec by opening the valve instantaneously from a state of full closing to a certain degree of opening (i.e., mid-position or intermediate position), and then making the valve move to a state of full opening after a short lapse of time, and (2) the water hammer cannot be prevented if the afore-mentioned initial halt position of the valve body, that is, the degree of valve opening, is either greater or smaller than a specific value.

[005~~941~~] Figure 5(a), (b), (c) show ~~the~~ pressure changes in the pipe passage on the upstream side of the valve 4 when the step pressure Ps is made to changed from 0.245MPa · G to 0.255MPa · G to 0.274MPa · G, and the pressure Pa of the actuator is made to changed as 0→0.245→0.49MPa · G, to open the valve 4 fully in 100m sec.

[006~~042~~] Figure 6 is an enlarged view of~~what~~ the afore-shown Figure 5(c) ~~is enlarged~~. It becomes apparent that ~~the~~ vibration of the pipe passage L_1 on the upstream side can be made nearly zero by fully opening the valve 4 with a~~the~~ 2-step operations to raise the pressure Pa of the actuator in the order of 0→ 0.294→0.490MPa · G in about 1000m sec.

[0061~~43~~] Figure 7(a), (b), (c) show ~~what surveyed on~~ the relationship observed between the step pressure Ps and the vibration pressure in the pipe passage L_1 on the upstream side in the cases where the internal pressure of the tank is made to be 0.098, 0.196 and 0.294MPa · G_1 respectively. Thus, it becomes apparent that there_-

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exists a~~the~~ step pressure Ps that~~which~~ minimizes ~~the~~ vibration pressure for each case. In these cases~~Here~~, ~~a~~ holding time of the step pressure is ~~made to be~~ 1000m sec.

[0062~~44~~] Figure 8 is an explanatory drawing of the supply pressure Pa to the actuator 4a in the test of the afore-shown Figure 7, and shows the relationship of ~~the~~ positioning of the step pressure Ps and the first step (point A) and the second step (point B).

[The First Embodiment of a Water Hammerless Opening Device]

[0063~~45~~] Figure 9 ~~and Figure 10~~ illustrates the basic block configuration of the first embodiment of a water hammerless opening device for the fluid passage according to the present invention. The device is mainly used when it is found difficult to mount a pressure detector, such as 3, ~~Pc~~ on the pipe passage L_1 on the upstream side that~~which~~ has been already installed, or to mount a valve stroke detector (a position detector) on the valve body 10.

[0064~~46~~] Referring to Figure 9 and Figure 10, the~~said~~ water hammerless opening device is made by assembling a valve body 10, an actuator 11, an electro-pneumatic conversion control device 17, a computation control device 16

thatwhich makes possible the control possible over the step switching of the actuator operating pressure Pa, and the pressure holding time Ts after having been switched and the like. A, and a vibration sensor 18 is removably fixed to the pipe passage L_1 on the upstream side so that the conditions of opening of the valve body 10, which make water hammerless opening possible, are set and stored beforehand by appropriately selecting the step switching of the actuator operating pressure Pa (switching from 0 to the step pressure Ps in Figure10(a)) applied to the actuator –

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11 of the valve body 10 and also the holding time Ts of the step pressure Ps.

[006547] More specificallyNamely, with respect to Figure 9 and Figure 10, 16 designates thea computation control device, 17 is thean electro-pneumatic conversion control device, 18 is a vibration sensor, 6 is a valve driving gas source, 10 is a valve body and 11 is an actuator. The driving pressure Pao (approximately 0.6MPa in this embodiment) from the valve driving gas source is converted to the step operating pressure Pa as shown in Figure10(a) by the electro-pneumatic conversion control device 17, and then is applied to the actuator 11.

[006648] The actuator operating pressure Pa applied to the actuator 11, and its holding time Ts, are controlled by the control signal Sc from the computation control device 16 determined beforehand by the operating test whereinef opening of the valve body was conducted for each pipe passage L_1 on the upstream side of the valve beforehand in athe manner described later. TheSaid vibration sensor 18 and computation control device 16 are removed

from the pipe passage L_1 on the upstream side upon completion of the selection ofselecting the afore-mentioned control signal Sc by employing the operating test foref opening the valve body 10.

[006749] TNamely, the afore-mentioned computation control device 16 is equipped with a setting circuit 16a for receiving the step pressure setting signal Ps, a setting circuit 16b for receiving the pressure holding time setting signal Ts, a setting circuit 16c for receiving the permissible upper limit vibration pressure setting signal Prm, a pipe passage vibration pressure detecting circuit 16d, a comparison computation circuit 16e, and the like. T, and to which the vibration detecting signal Pr, by which changes in the internal pressure P_1 detected by the vibration sensor 18 at the time of opening of –

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the valve body 10 are considered, the step pressure setting signal Ps, the step pressure holding time setting signal Ps, and the permissible upper limit vibration pressure setting signal Prm are inputted, respectively, to the computation control device 16.

[006850] TAnd, the vibration detection signal Pr and the permissible upper limit vibration pressure setting signal Prm are compared at the comparison computation circuit 16e. When athe difference is found between them, as described later, the step pressure setting signal Ps is corrected so that the control signal Sc includes theing said corrected step pressure step pressure setting signal Ps and the holding time setting signal Ts. The control signal Sc is outputted to the data storing part 17a of the electro-pneumatic conversion control device 17.

[00695~~4~~] Also, the afore-mentioned electro-pneumatic conversion control device 17 is equipped with a data storage part 17a, a signal conversion part 17b (i.e., a signal generator 7), an electro-pneumatic conversion part 17c (i.e., an electro-pneumatic conversion device 5), and the like. The actuator operating pressure Pa supplied to the actuator 11 is switched and converted in ~~the~~ steps, as shown in Figure 10(a), by the actuator operating pressure control signal Se from the signal conversion part 17b that is~~being~~ inputted to the electro-pneumatic conversion part 17c.

~~———~~The switching signal So corresponding~~to correspond~~ to the valve opening/closing command signal S and the operating situation (NO = normally open or NC = normally closed) of the valve body 10 is inputted to the~~said~~ electro-pneumatic conversion control device 17.

[00706~~2~~] Referring to Figure 9, firstly a vibration sensor 18 is fixed to the pipe passage. Next, the appropriate step pressure setting signal Ps, step pressure ~~25~~

holding time setting signal Ts, and permissible upper limit vibration pressure setting signal Prm, are inputted to the computation control device 16, and the valve body switching signal So of the electro-pneumatic conversion control device 17 and the actuator operating fluid supply pressure Pao are appropriately set.

[00715~~3~~] Then, by inputting the valve opening/closing command signal S, the actuator operating pressure Pa, for example, like a form shown in~~of~~ Figure 10(a), is supplied to the actuator 11 of the valve body 10.

~~———~~Now, when the actuator operating pressure Pa is raised from 0 to Ps at

~~a~~ time t_1, the fluid passage of the valve body 10 is opened up to its mid-position, and the valve body 10 is in thea state of full opening whenby the actuator operating pressure Ps isbeing made to be Pamax at ~~a~~ time t_2 when, further, the set holding time has elapsed.

[00754] Meantime, if the internal pressure P_1 of the pipe passage L_1 changes due to the occurrence of a water hammer, the changes are detected by the vibration sensor 18 and the vibration detecting signal Pr is inputted to the computation control device 16.

In the computation control device 16, the detecting signal Pr and permissible upper limit vibration pressure setting signal Prm are compared, and when it is found that there occurs no vibration or the vibration is within tolerance at a position A_1 (time t_1), but the vibration exceeds tolerance Prm at a position A_2 (time t_2), the step pressure setting signal Ps is corrected to raise the actuator operating pressure a little so that the corrected step pressure setting signal Ps, ~~26~~ and corresponding holding time setting signal Ts ~~thereof~~, are outputted as the control signal Sc from the computation control device 16 to the electro-pneumatic conversion control device 17, and the same operating tests for opening the valve body are thereafter repeated ~~thereafter~~.

[00755] Conversely, when it is found that ~~the~~ vibration occurringed at a position A_1 (time t_1) exceeds the permissible upper limit vibration pressure setting signal Prm, the setting signal Ps is corrected to lower the afore-mentioned step pressure setting signal Ps a little, and outputted as the control signal Sc from the computation control device16 to the electro-pneumatic

conversion control device 17, and the same operating tests for opening the valve body 10 are repeated thereafter.

[007456] Through repeatinged operating tests as describedstipulated in the above paragraphs [006446] and [006749], the intermediate operating pressure Ps (the step pressure setting signal Ps) for the actuator 11, required for water hammerless opening of the pipe passage L_1 equipped with a vibration sensor 18, is selected for the specified step pressure holding time setting signal Ts (the valve opening time Ts). The selected control signal Sc, bywith which the optimum step pressure setting signal Ps and holding setting time Ts –willfor not causeing a water hammer, are given is stored in the data storage part 17a of the electro-pneumatic conversion control device 17, and the pipe passage L_1 is opened from then on by controlling the actuator operating pressure Pa based on the stored control signal Sc.

[007557] In accordance wWith the embodiment in the afore-shown Figure 9 and Figure 10, the present inventionit is so made that the actuator operating pressure Pa is controlled in 2 steps.__—

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However, it goes without sayingthere is no need to say that the inventionit can be switched in 3 steps or 4 steps when necessary.__—

————Normally, the step holding time setting signal Ts is set between 0.5~1 second. It also goes without sayingThere is no need to say that the shorter thesaid time Ts becomes, the more difficult it becomes to find the conditions for water hammerless opening.

[The Second Embodiment of a Water Hammerless Opening Device]

[007658] Figure 11 illustrates the second embodiment of the method of opening a fluid passage, and the water hammerless opening device for which the method is used, according to the present invention.

In Figure 11, L_1 designates a pipe passage, 10 is a valve body, 11 is an air actuator, 18 is a vibration sensor, 19 is a tuning box and 20 is an electro-pneumatic conversion device. The basic configuration as a water hammerless opening device is almost the same as that of the first embodiment shown in Figure 9.

[007759] The afore-mentioned tuning box 19 is for optimizing the actuator operating pressure Pa in 2 steps supplied to the air actuator 11 usingby the vibration detecting signal Pr, provided byfrom the vibration sensor 18 mounted on the upstream side of the valve body 10 and which is being inputted as a feedback signal. The tuning box is for to detecting the occurrence of a water hammer from thesaid feedback signal Pr and is forto outputting the control signal Sc, for the actuator operating pressure, to the electro-pneumatic conversion device 20. SpecificallyConcretely, as described later, the optimal values for the step operating pressure Ps' of the actuator operating pressure Pa and the step operating pressure holding time t, as shown in Figure 15, are computed. T, thus, outputting the control signal Sc may be outputted to the electro-pneumatic conversion device 20, which will to make thesaid

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actuator operating pressure Pa output from the electro-pneumatic conversion device 20 to the actuator 11.

[007860] TheSaid tuning box 19 is equipped with a selector switch for switching the control signal Sc corresponding to the type of operation (N.O. or N.C.) of the air actuator 11 of the valve body 10.

[007964] Figure 12 shows one example of the PC screen display thatwhich forms athe major part of the tuning box. The screen display is so constituted so that a state of opening/closing of the valve body 10, the actuator operating pressure Pa to the air actuator 11, circumstances of the vibration of the pipe passage L_1, the step operating pressure Ps' and pipe vibration values, the condition setting for auto-tuning, the condition setting for manual opening/closing, the operation type of the valve body 10, and others information can be displayed on the screen.

[008062] The signal converter and electro-pneumatic converter are combined to make the afore-mentioned electro-pneumatic conversion device 20. As shown in Figure 13, the electro-pneumatic conversion device 20it comprises an air inlet electromagnetic valve B2, an air outlet electromagnetic valve F, a pressure sensor E, a control circuit A2, and others. Basically, theits configuration is almost the same as those shown in Figures 2(a) and (b).

[008163] In particularNamely, anthe air pressure higher than 0.6MPa is supplied to the air inlet electromagnetic valve B2, and anthe air pressure of 0~0.5MPa is outputted to the actuator 11 as the actuator operating pressure Pa. The control circuit A2 of thesaid electro-pneumatic conversion device 20 is equipped with the substrate A_1, the outside input/output interface A_0, and others. 29

The outside input/output interface A_0 is equipped with two connectors Ac and Ad.

A power supply source (DC24 or 12V), an opening/closing signal I (voltage input or non-voltage input) and a pressure monitor (0~5DCV · 0~981KPaG) are connected to the connector Ad, while thea tuning box 19 is connected to the connector Ac.

[00826] Figure 14 shows the implementation flow of the auto-tuning in thesaid second embodiment. Figure 15 shows the relative relationship between the actuator operating pressure Pa applied to the actuator 11 and the occurrence of the vibration.

As in the case of Figure 10, the 2-step actuator operating pressure, in 2 stepsas shown in Figure 15, is applied as the actuator operating pressure Pa.

[00836] Referring to Figure 14, and as shown in Figure 11, the vibration sensor 18 is fixed at a prescribed position of the pipe passage L_1 (a position on the upstream side within about 1000mm from the valve body 10, or preferably a position of 100~1000mm away to the upstream side), and a tuning box 19 and an electro-pneumatic conversion device 20 are set, respectively.

Next, the valve is held in a state of full closing for about 2 seconds (step S_2) bywith the input (step S_1) of the auto-tuning start signal, and then thee actuator operating pressure Pa is applied in 2 steps for conductingthe control being conducted (step S_3). As described later, the holding time t of the step operating pressure Ps' has been set between 0.5~1 sec.

[00846] The vibrations caused on the pipe passage L_1, when the valve body 10 is opened, are detected and confirmed (step S_4) by the vibration detecting signal Pr.

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from the vibration sensor 18, and ate check is made to see whetherif the vibrations are caused at the point Av or at the point Bv (step S_5, step S_6). When it is found that the vibrations are caused at the point Av, the step operating pressure Ps' of the actuator operating pressure Pa is reduced (step S_7), while when it is found that the vibrations are caused at the point Bv, the afore-mentioned step operating pressure Ps' is raised (step S_8).

[008567] The actuator operating pressure Pa having the optimum step operating pressure Ps', with which no vibration is caused, is eventually obtained by repeating the control of the opening of the afore-mentioned valve body 10 (normally over 2 or 3 to 15 times). Then the valve body 10 is made to open by inputting the control signal Sc obtained through auto-tuning of the electro-pneumatic conversion device 20 to output the actuator operating pressure Pa in 2 steps, with which completely prevents the vibrations are completely prevented, obtained through the auto-tuning to the electro-pneumatic conversion device 20.

[008668] The shorter is set the step operating pressure holding time t of the 2-step actuator operating pressure Pa, in 2 steps applied at the time of the afore-mentioned auto-tuning, the better. However, when usingwith a pneumatically operating actuator 11, it is desirable that the time t is less than 1 second.

FromWith afore-shown Figure 14 and Figure 15, an illustrationthe explanation is given for the case where athat the normally closed type pneumatically operating diaphragm valve is employed, and the valve of the valve body 10 which valve is closed and thenis made to open by supplying the

actuator operating pressure Pa. However, it goes without sayingthere is no need to say that a water hammerless opening can also be achieved by employing athe normally open type pneumatically operating diaphragm valve so thatand reducing the

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actuator operating pressure Pa in 2 steps opens the valve. In this case, it should be noted that the adjustments of the step operating pressure Pa' of the actuator operating pressure Pa are the reverse of the case of when the afore-mentioned normally closed type pneumatically operating diaphragm valve is used., That is, when the vibrations are caused at the time when of the actuator operating pressure Pa in the first step isbeing reduced in the first step, the step operating pressure Pa' is then raised, while when the vibrations are caused at the time when of the actuator operating pressure Pa in the second step isbeing reduced, then the step operating pressure Pa' is lowered.

[008769] Figure 16 illustrates thea relationship between the step operating pressure holding time t and the pressure rising value △P(MPaG) when the pneumatic pressure operating valve (19.05mm) is employed, with which the inner capacity remains unchanged at the time when the valve is opened or closed, is employed, and 3 pipe passages with athe liquid line of 0.098MPa, 0.198MPa and 0.294MPa are opened with anthe operating pressure Pa having the actuator operating pressure Pa of 0MPaG→0.294MPaG→0.490MPaG in 2 steps. It has been determinedknown that if the step operating pressure holding time t is made to be more than 1 second, the pressure rise △P can reach nearly zero, and if t is made to be less than 0.5 second, the pressure rise

△P goes up.

[008870] Upon completion of the afore-mentioned auto-tuning, when the control signal Sc, which allows the water hammerless opening of the pipe passage L_1 (that is, the control signal for outputting the actuator operating pressure in 2 steps which allows forthe water hammerless opening), is determined, then data of the afore-mentioned control signal Sc (that is, the operating pressure Pa) are

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transmitted to the electro-pneumatic conversion device 20 that, to stores the data separately. T, thus, the tuning box 19 and the vibration sensor 18 are no longer necessary and may bebeing removed from the system.

[008971] When it becomes necessary to urgently openthat the valve body 10 is opened urgently, the 2-step actuator operating pressures Pa, in 2 steps which permitallows the water hammerless opening, are outputted from the electro-pneumatic conversion device 20 to the actuator 11 of the valve body 10 by employingusing the data on the afore-mentioned control signal previously determined through the auto-tuning beforehand.

[009072] With respect to the embodiment in the afore-shown in Figure 11, when the actuator operating pressure Pa (the step operating pressure Ps' and the holding time t thereof) is determined upon completion of the auto-tuning operation, the data on thesaid operating pressure Pa are transmitted to the electro-pneumatic conversion device 20; thus, the vibration sensor 18 and the tuning box 19 are completely removed thereafter from the system. However, it goes without sayingthere is no need to say that the tuning box 19 may beis

downsized so that it can be integrated with the electro-pneumatic conversion device 20.

[009173] Figure 17 is a system diagram ~~to~~ illustrating how the method of supplying chemical solutions according to the present invention is applied to a~~the~~ single wafer processing cleaner that~~which~~ constitutes a semiconductor manufacturing facility. According to~~With~~ Figure 17, A_0 designates a fluid supply system, 10 are valve bodies~~y~~ installed in the fluid supply system A_0, B_0 is a single wafer processing cleaner, L_0 is a pipe passage, W is a wafer, A is a mixed chemical solution (ozonized ultra-pure water · the concentration of ozone 2~3ppm), B is a mixed chemical solution of hydrofluoric acid, hydrogen peroxide, ultra-pure water (mixing ratio 0.03:1:2), C is a –

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mixed chemical solution of ammonium hydroxide, hydrogen peroxide, ultra-pure water (mixing ratio 0.05:1:5), and D is ultra-pure water. The fluid supply system A_0 in Figure 17 is constituted in the form like, for example, the afore-shown systems of Figure 1, Figure 9 or Figure 11. The system of Figure 17~~It~~ is so constituted that, firstly, the valve of the valve body 10 is moved in the direction of ~~the~~ valve opening through ~~the~~ mediation of the actuator (not illustrated) by a given degree, and next, the valve~~it~~ is held as it is at the given degree of valve opening (i.e., mid-position or intermediate) for a short period of time, and then the valve is moved to the position of full opening so, ~~thus~~ the valve body 10 is fully opened.

[009274] The constitution and action of the fluid supply system A_0 are exactly the same as those in the systems of afore-shown Figure 1, Figure 9 or Figure 11.

Therefore, further~~the~~ explanation of these alternate embodiments is omitted ~~herewith.~~

~~———~~The cleaning process of a wafer W is that, first~~ly~~ cleaning is performed using~~with~~ the mixed chemical solution A, and next, the mixed chemical solution B is supplied, and then the mixed chemical solutions C and D are supplied in turn as~~by~~ the valve body 10 is~~being~~ switched through ~~the~~ mediation of the actuator.

[009~~375~~] At the time ~~of supplying~~ the chemical solutions A, B, C and D are supplied, it is desirable that the pressure rise value in the pipe passage L_1, occurring~~ed~~ when the valve body 10 is opened, is kept within 10% of the pressure value before the valve is opened. In order that the pressure rise value is kept within the afore-mentioned 10% limit, some adjustments are made for the driving input value to the afore-mentioned actuator and also for the corresponding holding time ~~thereof~~. The pressure rise value in the pipe passage L_0 can be kept within 10% of the steady state value by maintaining~~making~~ the pressure rise value in the pipe passage L_1 within 10%.

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Furthermore, with respect to the embodiment discussed above, ~~the~~ explanation is provided~~given~~ only for the upper limit of the pressure rise value at the time ~~of~~ ~~the start of~~ supplying of mixed chemical solutions A, B, C and D (or at the time of the valve being opened) is started. However, it goes without saying~~there is no need to say~~ that there exists an~~the~~ upper limit for the pressure rise value for~~of~~ the pipe passage L_1 at the time of halting the ~~halt of~~ supplying of mixed chemical solutions A, B, C and D (or at the time of the valve being closed). Each valve

body 10 in Figure 17 is operated for closing so that the afore-mentioned pressure rise value is kept within the set value.

Feasibility of Industrial Use

[009476] The present invention is applicable not only to ~~the~~ supply pipes for water, steam, and the like, used in industries, but is also applicable to ~~the~~ supply pipes for household water/hot water. The present invention~~It~~ is also applicable to ~~the~~ supply pipes for fluids (gases and liquids) used in ~~the~~ semiconductor manufacturing plants, chemical plants, and the like. The present invention is particularly suited for application~~applying~~ to chambers~~-~~, wafer cleaning devices or various types of etching devices used for semiconductor manufacturing.